

Thermoregulation and Heat Illness

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Abnormal VS?

T=39C (102.2F)

HR=175

RR=50

Heat Illness?

- 35 yo ♀ seasoned ultrarunner UK
- BMI 23
- 100K race in Thailand
- Progressive melt down despite adequate po

WBGT Color Flag Heat Index Risk

Black	28°C (82°F)	Extreme
Red	23-28°C (73-82°F)	High
Yellow	18-23°C (64-73°F)	Moderate
Green	<18°C (64°F)	Low

Limitations

- Environmental
- Physiological
- Exercise intensity

Acclimate!

Plasma volume **expansion**

↑ Cutaneous Blood Flow

↓ Threshold for sweat initiation

↑ sweat output, ↓ Na⁺ concentration in sweat

How do we stress?

- Heat
- Altitude
- Weight Vest
- Hills



Heat Illness: “spectrum”

Cramps

Exhaustion

Syncope

Collapse

Stroke

(Heat) Cramps: Postulated

- Dehydration
- Loss of sodium and/or potassium
- Extreme environmental conditions
- Neurogenic fatigue

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(Heat) Cramps

- Core temperature: Normal or mildly elevated
- Electrolytes: Normal
- Occur in all temperatures
- Swimmers, hockey players

Exercise Associated Muscle Cramps

“As a result of the controversy surrounding the etiology of muscle cramps... “exercise associated muscle cramping” (EAMC)

Muscle cramping in athletes--risk factors, clinical assessment, and management.

Schwellnus MP, Drew N, Collins M

Clin Sports Med. 2008;27(1):183.

Treatment: non-evidence based

- IV Fluids
- Neuroinhibition techniques

(Heat) Syncope: Misnomer

Not direct cause of syncopal
event (ie, core body
temperature is not significantly
elevated)

(Heat) Syncope: Misnomer

Most common in unacclimated

- Prolonged or sudden standing in the heat with little movement

Exercise Associated Collapse (EAC)

- Occurs immediately post *prolonged* exercise
- Mechanism for collapse: Decrease in venous return after stopping
- Heat indirect contributor to EAC



Medical Tent
at Ironman:

EAC #1!

End of Event:

- EAC
- SCA
- Hyponatremia (EAH)
- Heat Stroke

Mid Event:

- SCA/Arrhythmia
- Hyponatremia
- Heat Stroke
- EAC/heat exhaustion

Mid Event Collapse: More dangerous

Heat Exhaustion:

- Unacclimated
- Larger body mass
- Measure core temp ($T < 40.5$)

Treatment EAC/(Heat) Syncope

:

- Covered tent/shade, place in Trendelenberg
- Give po fluids
- Avoid sudden or prolonged standing until fully recovered

Rapid Recovery is the Norm

15 to 20 minutes

Failure to improve:

- rectal temperature (core temp $< 40.5^{\circ}$ C)
- sodium level
- possible hospital transport

End of the “Heat Spectrum”

“Heat Injury” and Heat Stroke

“Heat Injury” not an “official” ICD code

Term coined by the military for describing severe exertional heat illness **without** neurological symptoms

Heat Injury vs Heat Stroke

(>40.5°C/104.9° F)

Injury

- Hyperthermia and end organ damage, but *without* any significant neurologic manifestations
- Organs commonly damaged include the muscles, kidneys, and liver

Stroke

- End organ damage AND CNS findings
- CNS symptoms include altered mental status, seizures, abnormal behavior

Box 1: Symptoms and signs of hyponatremia

- None
- Headache
- Lethargy
- Dizziness and ataxia
- Mild confusion
- Psychosis
- Seizures
- Coma

Overlap between heat illness and hypo Na⁺

- Strenuous exercise in high ambient heat/humidity
- Lack of acclimatization
- Poor fitness

Not easy: Heat injury vs stroke

- ✓ Clinical diagnosis
- ✓ CNS dysfunction (seizure, AMS, abnormal behavior).
- ✓ often retrospective Dx

Heat injury/stroke: $T > 40.5^{\circ}\text{C} / 104.9^{\circ}\text{F}$

For *any* suspected serious heat injury, rapid **cooling** is mandated and can be life saving

Cooling is only effective treatment!

- No medications are helpful
- Secondary survey (in hospital):
labs, IV hydration, seizure
management, arrhythmia,
rhabdomyolysis

Suspect Heat Stroke? Don't Delay

Any CNS signs + Rectal Temp >
40.5°C/104.9°F



Empiric Treatment

- Treat with ice/cold water immersion for 15 to 20 minutes.
 - Cool majority 3 to 4°C (5 to 7°F)
- (Assumes nearly all patients are between 41 and 43.5°C at the time of the incident (106 and 110°F))

Tool Kit of Medical Tent

- AED
- Rectal thermometer(s)
- IStat or similar to measure Na, glucose
- Cooling ice baths (pre set-up)
- Army Style Cots and elevated foot stools

1000 Ways to Die can be narrowed to three biggies:

- *SCA: dramatic, variable, 1:90,000 marathon*
- *Hyponatremia: common*
- *Heat Stroke: uncommon in mass events, but...*

Heat Stroke is a major problem:

- High School Football Linemen, in August practice, especially in FL, AZ, and TX
- Incidence about 1 in 30,000
- **Ten** times death rate of any other sport

Where we left off

- Heat Illness: Not a spectrum
- Acclimation
- Heat is a *Stressor* and Contributor to Syncope, EAC, Exhaustion
- Not true heat illness, core temp < than 104.9 F/40.5C)

Your Brain Protects You

Feeling Overheated

does not equal

being Overheated

“Heat” Exhaustion

Can be prevented with
acclimation and
reducing exercise intensity

Potential fatal events

- SCA/Arrhythmia
- Hyponatremia (EAH)
- Heat Stroke

Heat Stroke

Noakes:

“Heat fatigue, heat exhaustion, and heat syncope should be removed from the modern lexicon.”

Heat Stroke-Noakes continued

“Heat stroke is ...the only condition in which there is clear evidence for a pathological elevation of the core body temperature.”

Overheating in the lab

Maximal effort running studies:

Humans almost always **stop** exercise when their body temperature hits 40C (104F).

“Critical limiting temperature”

In Real Life

Allow athletes to choose their own pace..

- And they will slow down long before they overheat
- Noakes labeled “Anticipatory Regulation” of exercise by the brain.

So, a problem: How to pass 40°C?

Maybe: Exceptional fortitude and can push past the limit

But: Very rare in elite athletes, most likely to have this “mental override” capacity.

Too easy: Heat stroke happens because people “push themselves” too hard in the heat.

Overdiagnosis?

“Man drops dead from heat stroke during marathon”

“Football player sudden death during practice in crippling heat”

Often Diagnosed:

Without measuring core body temp

Unknown Cardiac disease, either structural or acquired

- Estimated at perhaps 1 in 40,000 adults
- Add physiological stress of marathon or triathlon+ difficult conditions
- In races of up to 50,000 participants
- Would expect some adverse events

Controlled Hyperthermia

- Exercise can make the “abnormal” feel normal
- Brain can adjust “set-points”
- Humans are extremely efficient at heat loss

Heat Stroke

Problem of Physiology,
Not Environment

Calculating Heat Production

Heat Production: **Mass** x $\{(5.89 \times \text{speed}) - 4.69\}$

Football players

5K runners

Heat storage = Production - Loss

Convection
Radiation



Convection
Radiation
Evaporation

Heat Production

Heat Loss

Proportional to:

- Speed (intensity)
- Body mass

Affected by:

- Mech. Efficiency

Influenced by:

- Environmental conditions
 - Temperature
 - Humidity
 - Wind-speed
- Body size (surface area)

Source: Science of
Sport, Ross Tucker,
PhD

➤ If capacity heat loss > calculated heat gain, heat stroke is not possible

➤ If capacity heat loss < calculated heat gain, can accumulate heat and heat stroke is possible



Heat Gain

Heat Loss

From exercise	1380 W	384 W	Convective
Solar radiative gain	125 W	80 W	Radiative
		1107 W	Maximal evaporative capacity
TOTAL	1495 W	1571 W	TOTAL

The capacity of heat loss
EXCEEDS heat gain

Theoretically, heat stroke is **NOT**
possible

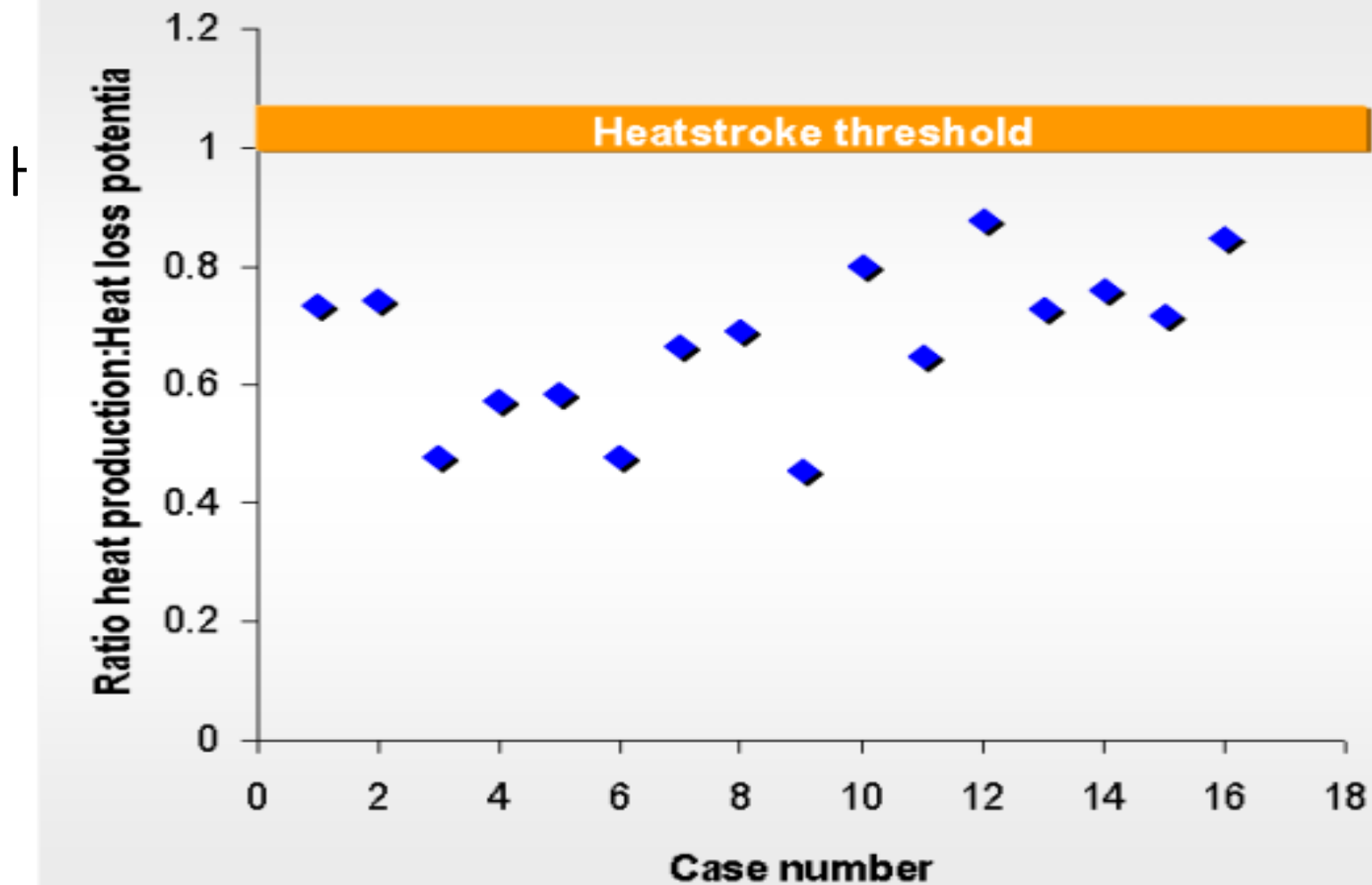
Heat Stroke!

16 minutes: Core Temp 40.8 (105.4)

- ❑ Only 2.5 miles
- ❑ Conditions: 72F, 80% humidity
- ❑ About =Turkey Trot Clearwater

EHS: Questions

1. Why so rare?
2. If it cannot be simply a function of exercising so hard that you overwhelm your body's capacity for heat loss, then what happens?
3. Why is it more common in back-of-the-pack?



Doesn't make physiological sense

➤ Every single case, the potential for heat loss ***EXCEEDED*** the amount of heat produced from exercise!

Heat Produced: Not from Exercise

“Excessive Endothermy” (Noakes et al)

Malignant Hyperthermia

- Ca channels open in unregulated fashion
- Usually presents with rigidity
- Possible genetic predisposition

Other possibilities

- Excess sympathetic activation
- Underlying muscle myopathy
- Underlying undiagnosed bacterial infection

What about decreased **heat** loss?

- ❑ Failed Evaporation or Convection
- ❑ Very unlikely: Failed Evaporation would suggest ***absence*** of sweating
- ❑ Contrary to popular belief, people with heat stroke are ***sweating profusely***

Rethinking Heat Stroke

- Possibly a general term, describing a **symptom, not a specific condition**
- Defined as a failure of normal physiology

Chicago Marathon 2007 (70-88F)

- More than 300 people were picked up by ambulances “suffering from nausea, heart palpitations and dizziness from the stifling heat”
- 49 hospitalized/250 treated at race-sponsored aid stations and a medical tent.
- 35 y/o male collapsed and expired at mile 18

What really happened?

- Vast majority not acclimated-(Normal temps in 50s)
- BP's drop in heat-could have led to collapse

(Only need rest/elevation to resolve)

- Altered perception of athletes

{Not correct=Overheated as $T < 40.5/104.9$ }

Heat Stroke

- It is not a common condition
- And does not develop simply by exercising on a hot day and failing to drink enough fluids

Summary

- Heat Stroke not always caused by exertional activity in hot temperatures
- Heat Illnesses do not represent the tidy continuum we were taught

Collapsed Athlete-Mid Race

- Rapid Assessment, glance at bib for Hx
- AED at the ready
- BLS Assessment-Most likely ACS vs Heat “Exhaustion”
- Elevate feet, Check rectal temperature
- If fails to improve rapidly, check Na/Glucose, transport

Collapsed Athlete-Finish

- Most likely EAC
- BLS assessment, supine, elevate feet
- Rapid improvement or obtain rectal temperature, Na, Glucose

Recommended Reading

A modern classification of the exercise-related heat illnesses.

Noakes, TD

J Sci Med Sport.: 2008 Jan;11(1):33-9. Epub 2007 May 23.

Suggested Readings

1. Endurance running and the evolution of Homo

Bramble, Dennis, and Lieberman, Daniel

Nature, Vol 432, 18 Nov, 2004

2. A modern classification of the exercise-related heat illnesses.

Noakes, TD

J Sci Med Sport.: 2008 Jan;11(1):33-9. Epub 2007 May 23.

Suggested Readings (2)

3. Metabolic rate, not percent dehydration, predicts rectal temperature in marathon runners.

Noakes TD, Myburgh KH, du Plessis J, Lang L, Lambert M, van der Riet C, Schall R

Med Sci Sports Exercise: 1991;23(4):443.

4. Heatstroke during endurance exercise: Is there evidence for excessive endothermy?

Rae, DE, Tucker, R, Noakes, TD et al

Med Sci Sports Exerc: :2008 Jul;40(7):1193-204